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Determination of the Ionospheric
Convection Pattern From DMSP Data

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DETERMINATION OF THE IONOSPHERIC
CONVECTION PATTERN FROM DMSP DATA

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ABSTRACT

Thermal plasma instrumentation on the DMSP-F8, DMSP-F9, and future DMSP satellites may provide the first continuous long-term database of the ionospheric flow over both polar caps. Flow data from the satellites can be combined with a model magnetic field to calculate both the form and magnitude of the potential distribution across the polar cap. We are developing a model that will take the information about the potential distributions seen by both satellites and allow us to model the convection pattern over the entire polar cap region. A description of the data application is given along with a comparison of model and observed potential distributions.

I. INTRODUCTION

After years of study it is generally accepted that the high-latitude ionospheric convection pattern usually consists of a two-celled pattern for southward IMF whose exact shape depends on the strength and orientation of the IMF. An exact analysis of this pattern has been hindered by the sporadic coverage of satellite observations of the convection flow. Using ion drift meters on the polar orbiting DMSP satellites F8 and F9 we are starting to assemble the first long-term database of convection flow. Using the flow data and a magnetic field model we compute the electrostatic potential distribution along the satellite's path. This data is used as input to calculate a model of the potential distribution over the entire polar cap. This paper demonstrates our current ability to measure the potential drop across the polar cap as well as preliminary examples of the resulting model of the potential distribution.

II. INSTRUMENTS

Ion drift meters (IDMs) have flown on several satellites including Atmosphere Explorer and Dynamics Explorer-2, and are currently part of the instrument compliment on the DMSP satellites, F8 and F9. The instrument is oriented with its entrance aperture facing along the direction of the satellite's velocity vector so that the ions stream through the aperture and onto a segmented collector. (Electrons are kept out by a small negative potential grid in front of the collector.) Ion flows perpendicular to the spacecraft velocity vector cause an asymmetry in the currents collected by the collector segments. The four collectors are arranged so that both horizontal and vertical flows can be measured. Using the known velocity of the spacecraft (which is usually much larger than the thermal velocity of the ions) and measuring

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the asymmetry of the currents to the collectors we can calculate the perpendicular ion flow velocities. The IDMs onboard the DMSP satellites each sample both the horizontal and vertical flows six times per second and can accurately measure flows of up to 3 kilometers per second. A more complete description of the general workings of the IDM is presented in Heelis, et al. [1].

III. SATELLITE DATA

The analysis in this paper is based on the IDM data obtained from the two DMSP satellites. DMSP-F8 was launched in June 1987 into a polar orbit fixed in local time approximately along the dawn-dusk meridian. DMSP-F9 was launched in February 1988 into a polar orbit fixed roughly along the 1000-2200 line of local time. Both satellites are in circular orbits of about 800 kilometers (500 miles) altitude thus completing one orbit every 104 minutes. This allows us to make a "snapshot" of the same region of each polar cap every 104 minute almost without interruptions for the entire lifetime of the spacecraft. Such complete coverage (which has not been previously available) will allow a more complete examination of the evolution of the polar convection pattern with time.

IV. ANALYSIS

For our analysis we must select times when the IMF is fairly constant so that the flow pattern remains stable. Since no IMF data for March 1988 was yet available, we chose to analyze a set of four polar passes that occur in the middle of a six orbit period during which the polar flow patterns seen by the IDM remain fairly unchanged. Two northern and two southern polar cap crossings were analyzed, though we are presenting only one of them in this paper. Fig. 1 and fig. 2 show (respectively) data from F8 and F9. This data details the horizontal and vertical flow data from the second southern polar pass in the set along with the calculated electrostatic potential distribution (see next section). Looking at the times along the x-axis shows that on this date the F9 satellite passes over each polar region about thirty minutes after the F8 satellite. We can combine the data from these complimentary passes in an attempt to model the potential distribution and convection flow pattern over the polar cap.

V. CALCULATION OF POTENTIAL DISTRIBUTIONS

The changes in potential along the satellite's path can be calculated using the available data from the IDM. Taking the perpendicular flow data combined with a model of the earth's magnetic field, we determine the electric field parallel to the spacecraft's velocity vector by using the basic MHD equation: $\vec{E} = -(\vec{v} \times \vec{B})$. Integrating this electric field along the satellite track produces an electrostatic potential distribution along the path the satellite travels over the polar region. Figs. 1 and 2 show the calculated potential distribution for the F8 and F9 (respectively) polar crossings we are

Figure 1. IDM data and calculated potential from F8 southern polar crossing

Figure 2. IDM data and calculated potential from F9 southern polar crossing

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studying. The integration begins when the satellite crosses the 50° magnetic latitude heading towards the pole, and is performed in four second increments thereafter until the satellite recrosses the 50° magnetic latitude line. The potential at the 50° magnetic latitude line is assumed to be zero, thus whatever offset remains at the end of the polar crossing is then used to add a linear correction to the potential distribution so that both ends are at zero potential. From this corrected potential distribution the location and magnitudes of the potential maximum and minimum are determined as well as the location of zero crossing and the potential at the highest latitude. These values serve as the inputs to a model of the global high latitude potential distribution.

VI. MODEL

The potential distribution pattern is determined using data from a single dawn-dusk pass. The model takes the magnitudes of the potential maximum and minimum along the dawn-dusk line as well as the potential at the origin, the location of the zero-line crossing, and the radius of the polar cap (defined as half the distance between the potential maximum and minimum). The model does a spline fit of the potentials from the maximum to the minimum through the zero-crossing point and the origin. The shift of the zero-crossing point determines the angle of the dayside zero line from the 1200 hour line (while for simplicity the nightside zero line is always drawn along the 0 hour line). The magnitudes of the potential maximum and minimum are used to determine the angular size of the maximum and minimum regions along the polar cap boundary. The remaining potentials along the polar cap boundary are calculated by a spline fit from the ends of the maximum and minimum regions through the zero-crossing line locations. Optimization of the procedure is not performed here. Once all the potentials along the polar cap boundary are known, then the potential at any point inside the polar cap can be calculated. This is done with a three-point spline fit along a line through the requested point and the origin which uses the potentials on the boundary and at the origin as the inputs. The potentials outside of the polar cap are calculated from the expression $(sin\theta/sin\theta_0)^{-n}$. Fig. 3 shows the potential patterns derived from the F8 data and presented in a magnetic latitude/magnetic local time coordinate system. The tracks of F8 and F9 are plotted over this pattern along with the locations of their maxima (plus signs), minima (closed circles), and zero-crossing points (open circles). While each orbital track of F8 may not move exactly along a 0600-1800 hour line in this coordinate system, the values from the satellite data may be used to extrapolate the necessary values for that line.

VII. COMPARISON OF MODEL TO DATA

Once the potential distribution model for the polar cap has been generated we can sample it along any satellite track to predict what potentials the
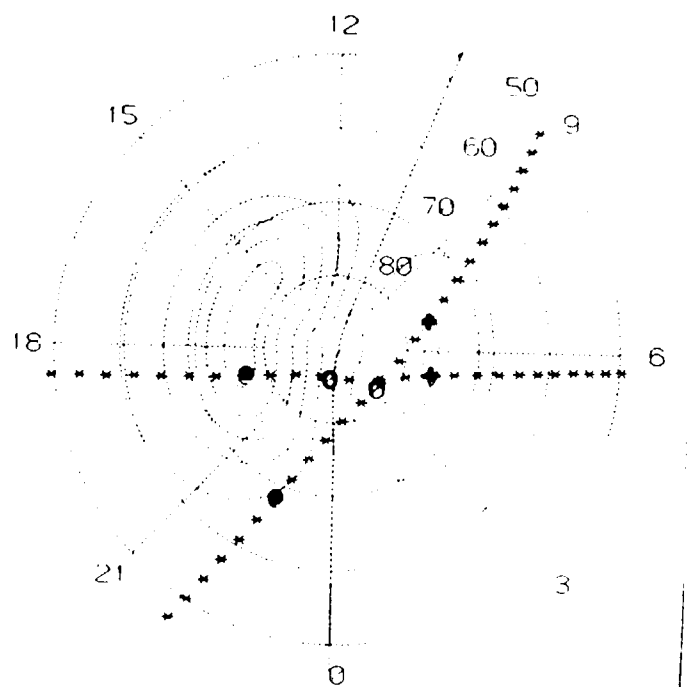
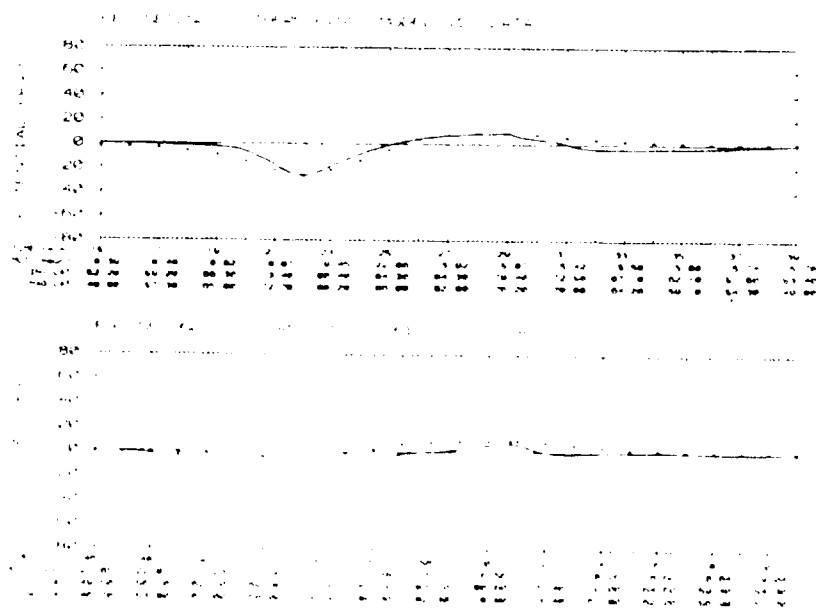Figure 3. Model of potential distribution pattern with satellite tracks from F8 and F9 passes.

Figure 4. Comparision of calculated potentials observed by satellites to model predictions.

satellite should encounter. In these cases we use the potential distribution from the F9 passes to check the model. Fig. 4 shows the actual potential distributions for this one polar pass compared with the values from the model (shown as asterisks) plotted for each minute and for the maxima and minima points. The F8 distributions match fairly well, which is to be expected since the models are based on them. Both the F9 southern polar passes show a fair amount of agreement with the model while both the F9 northern polar passes are marginal at best. This is likely due to the lower quality of the data from the northern polar passes at this time of the year, and the lack of optimization in fitting the local time distribution of the boundary potential. Overall, this simple model is an encouraging start to our goal of matching the potential distribution observed by both satellites.

VIII. CONCLUSIONS

We have demonstrated the capability to define the electrostatic potential distribution across the polar ionosphere using the data from the ion drift meters (IDMs) onboard the DMSP F8 and F9 satellites. Using this data as inputs we have constructed a simple first-order model of the potential distribution for the entire polar cap region. When checked against the actual potential distribution data from the satellites this model shows a fair amount of agreement. The model is still in the process of being developed and we plan to use the data from the DMSP satellites to further correct and refine it. Combining this exercise with available IMF data should eventually provide a large enough dataset to do a thorough statistical analysis of convection patterns and their relationships and responses to the IMF.

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